TROPICAL AGRICULTURE

THE OFFICIAL JOURNAL OF THE
IMPERIAL COLLEGE OF TROPICAL AGRICULTURE

VOL. XVIII, No. 11. NOVEMBER, 1941. PRICE 6d.

CONTENTS.

	PAGE.
The Use of Pot Cultures in Assessing Soil Fertility	209
The Control of Slugs by Meta Bait in Trinidad, B.W.I.	211
Assessment of Fertility of Abnormal Soils—(A) Rendzina or Humus—Carbonate Soil	214
Modern Soil Classification and Mapping...	222
Miscellaneous Notes	225
The Utilization of Cultivated Fodder Grasses in Trinidad	226
Chemical Notes	228

THE IMPERIAL COLLEGE OF TROPICAL AGRICULTURE, TRINIDAD, B.W.I.

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THE USE OF POT CULTURES IN ASSESSING SOIL FERTILITY.

ONE of the most important ecological factors affecting plant growth is the medium in which it takes place, namely, the soil. That there are "good" and "bad" soils has been known for centuries, and, for ages, farmers have adopted certain practices which they have learnt from experience to be beneficial in improving the productivity of soils. The elements which exert the most marked effects on the growth of plants were soon found to be nitrogen, phosphorus and potassium, and thus it became important to discover methods whereby the amounts of these elements in the soil, and their availability to plants could be determined. Laboratory methods were duly evolved by means of which the amount of a particular element under consideration was estimated by chemical analysis of extracts obtained generally by shaking or boiling a certain quantity of the soil with a definite amount of water or weak acid. These chemical methods were quite arbitrary, however, and they often indicated the nutrient status of the soil to be vastly different from that demonstrated by field experiments. Moreover, the results could not be applied indiscriminately to all soils and to all crops. In spite of this, many useful analytical laboratory methods have been developed by soil investigators in various parts of the world, and certain of them may now be claimed to give very useful results, provided the analyst has a knowledge of the soil under examination, and also of the nutrient requirements of the crop which it is intended to grow. If the soil is of an abnormal type, however, or if the chemist has had little experience of its behaviour in the field, serious errors may be made in estimating its nutrient status in the laboratory.

The ultimate proof of the value of a soil analysis is a field experiment properly laid out whose results are statistically analysed, but such experiments are expensive to carry out and take up much time. Moreover, they often interfere considerably with the normal running of a farm or estate. With the object of removing many of the difficulties and drawbacks of laboratory analysis and field experiments, several systems of examining soils by means of pot cultures of plants have been developed. Using suitable pots, it is comparatively easy to try out

many more treatments than would be possible in a field experiment. At the same time, these treatments may be replicated and the results statistically analysed. The plant itself acts as an extracting agent of the soil, and the sufficiency or otherwise of nutrients in the soil is indicated qualitatively by the amount of growth of the plant, and eventually by the dry weight of the crop at harvest. Often the mere visual difference between the various treatments is sufficient to demonstrate conclusively that one treatment is better than another. For the purpose of more accurate assessment, Professor E. A. Mitscherlich, after many years' work on the subject, has established certain growth laws which may be expressed mathematically. He has developed a standard pot technique by which he claims it to be possible, not only to determine the nutrient content of a soil quantitatively, but also to calculate from the results of his test how much fertiliser should be added to a soil under examination in order to produce a certain yield of crop. The Mitscherlich method has been widely applied in Germany where numerous stations have been started and run on business lines. It has not received much attention elsewhere, but is used to a considerable extent in Hawaii, and preliminary work on the method and its application to tropical conditions has also been carried out at the Imperial College of Tropical Agriculture.

Apart from their value in assessing the three major nutrients in plant nutrition, pot tests are also most valuable for determining the need of plants for the so-called "trace" elements, as well as various supposedly-important organic compounds and vitamins. In these cases, it is unlikely that laboratory analyses would be of very great assistance, as so little is yet known about the requirements of plants for these materials. On the other hand, it would be very expensive and hardly economic to lay down full-scale field experiments for the purpose of testing their practical value.

Pot experiments are also very convenient for obtaining information on the behaviour of plants when grown in soils having different degrees of acidity, and, on their reactions to various additions of lime and organic manures. Thus, much work has been done in Hawaii and elsewhere on the important problem of phosphate-fixation in certain tropical soils, and numerous experiments have been carried out in the United States of America in connection with the nitrogen-fixing ability of various legumes. In this way, much useful information has been obtained which would have taken much longer and cost very much more to acquire had field experiments been used instead.

Some plants have been found to develop marked and specific symptoms if they are not receiving a sufficient supply of a certain nutrient. For example, tomato seedlings are very susceptible to phosphate-deficiency, and by growing them in cigarette tins in a soil which contains insufficient available phosphate, the characteristic symptoms appear in a few days, thus affording a quick and practicable method of testing soils for phosphate-deficiency without an elaborate outlay in apparatus and equipment.

Naturally, there are numerous disadvantages to pot tests, and it must not be assumed that they are completely conclusive. Thus, only a comparatively small soil sample is used, and this is necessarily procured to some arbitrarily-chosen depth. For example, Mitscherlich recommends sampling to 20 cm. depth, and allows for the "sub-soil" effect by multiplying the results obtained by a factor calculated according to the permeability of the sub-soil. The objection to this procedure may be removed to some extent by examining, by means of a pot-culture method, samples of soil taken from successive horizons in the profile, and in this way a complete "picture" of the nutrient status of the soil may be acquired. The soil sample needed for pot tests is small in bulk, though greater than that used in chemical tests. Hence it must be obtained carefully in the field if the results are to be of any value.

The selection of a suitable indicator plant for use in pot tests presents considerable difficulty. In many cases, the actual crop which it is intended to grow in the field may be grown in the pots. In other cases a closely related species, presumably having similar habits, might be employed. In the general determination of the nutrient status of a soil, it may be desirable, however, to use one indicator plant for one nutrient, and another plant for a different nutrient. The selection of a suitable indicator is largely a matter of experience, but the plant selected as indicator should have a good root system capable of exploring thoroughly all the soil in the pot. Moreover, it should have a convenient life-cycle and growth habit, be comparatively free from pests and diseases, and be responsive to the various nutrients for which the soil is being examined.

The pot culture method of assessing soil fertility has its limitations, but nevertheless possesses considerable advantages. Its main use would appear to be as a check on chemical laboratory analyses, particularly of soils which are abnormal, or about which little is known, and also as a means of predicting the sort of responses which might be expected from various manurial and other treatments which may be applied in field trials. Pot tests are not intended to displace either laboratory analysis or large-scale field experiments, but rather to link them together and to indicate the scope of the field treatments. Used intelligently in this manner, they should prove of great importance in helping the agriculturist to a better understanding of the properties and capabilities of his soils.

THE CONTROL OF SLUGS BY META BAIT IN TRINIDAD, B.W.I.

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Introduction.

Slugs are always present in Trinidad as garden pests, and, although their nocturnal habits account for their being seldom seen, the injury resulting from their attacks is familiar to all gardeners. They attack a great variety of plants, and are usually most abundant in the rainy season, when conditions are most favourable for their increase. They are also of some importance as agricultural pests, ranking as a major pest of sweet potatoes, which they damage probably more severely than any other crop. On the College Farm at St. Augustine, slugs always cause a certain amount of damage, especially to newly planted sweet potato cuttings. Occasionally they increase in numbers rapidly and become very abundant. When they attain epidemic proportions they may do considerable damage in a comparatively short time. One such outbreak occurred in December, 1939, when slugs were present in great numbers in a 3-acre field of sweet potatoes. The attack was most severe at the north end of the field, where plants were completely destroyed. This necessitated subsequent replantings, which were also destroyed in their turn.

The slugs attacking sweet potatoes at St. Augustine were determined as *Vaginulus langsdorfi* Férussac. They were at first thought to be the related species, *Vaginulus occidentalis* (Guilding), a widespread slug in the tropics, which attacks a great many plants. Specimens were submitted to Dr. H. A. Pilsbry of the Academy of Natural Sciences, Philadelphia, U.S.A. to confirm their identity. Dr. Pilsbry kindly reported that the specimens were not this species, but were *Vaginulus langsdorfi* Férussac, being determined by Dr. H. B. Baker, who has made special studies of the family to which this slug belongs.

Hand Collection.

The usual method of controlling these pests in the past has been the employment of boys provided with cans, who collect the slugs by hand during the day. The slugs collected are then usually destroyed by immersion in brine or kerosene. This method is very laborious and expensive. It is also comparatively ineffective as a control measure, as few slugs are caught in this way. During the day the slugs hide in cracks in the soil and under vegetation, or in other situations where they are protected from desiccation. They are nocturnal feeders, and hand collection would be much more effective as a control measure if practised at night with the help of an electric torch.

Poison Baits.

Since the discovery, apparently in South Africa some time prior to 1936, that Meta fuel is both highly attractive and extremely toxic to slugs, this substance has come into general use in the form of poison baits for the control of these pests. Meta is a proprietary product manufactured in Switzerland and originally sold as a solid fuel especially for use in small cooking stoves. The major constituent of Meta, if not the only one, is metaldehyde, a polymerized form of acetaldehyde. Meta is a white solid usually sold in the form of small tablets, but is also obtainable as a powder. It has now been put on the market for some time for the control of slugs, and is also sold with wheat bran in the form of ready-mixed slug baits. Meta is known to be dangerous to higher animals when eaten, and there are a few reports showing that dogs may be killed by eating Meta bait. It is also possible that birds may be poisoned by eating slugs killed by Meta.

The writer made some tentative experiments with Meta bait against slugs in Trinidad in 1937 and 1938, and found it to be most effective for the control of these pests. The bait used was about a 2 per cent. mixture by weight of Meta with wheat bran, *i.e.* 1 tablet (approximately 4 gms.) of Meta to 8 ozs. (approximately 227 gms.) of wheat bran.

This bait was also tried against the mole-cricket, *Scapteriscus vicinus* Scudder. Mole-crickets were given every opportunity of feeding on the bait, and, although some of it was eaten, the bait did not appear to be any more attractive than bran alone. No mole-crickets were killed by this treatment, and it was concluded that Meta bait is ineffective for the control of this pest.

Mr. L. J. C. Evans informs me that he had previously made an attempt to control slugs on the College Farm at St. Augustine by means of Paris green poison baits. The baits used were about 1 per cent. and 3 per cent. mixtures by weight of Paris green with coconut meal, corn meal or rice bran. These baits did not prove to be attractive to slugs, and, although examination showed that they had been visited, no feeding had apparently taken place. No slugs were killed by the application of these poison baits.

Experiments with Meta Bait.

During the severe outbreak of slugs at St. Augustine in December, 1939, the opportunity was taken to test thoroughly the effectiveness of Meta bait against these pests under Trinidad

conditions. The experiments were designed to find (1) how the effectiveness of the bait was affected by the use of diluents other than wheat bran, (2) the most suitable methods of applying the bait, (3) how long the bait remained attractive and retained its toxicity and (4) the cost of effective treatment.

Meta Bait Mixtures.

Meta used alone without the addition of any other substance is highly attractive and toxic to slugs. A relatively small quantity only is required, however, and it is necessary therefore to make use of a diluent for purposes of distribution. Baits used by other workers have usually consisted of from 1 per cent. to 4 per cent. mixtures by weight of Meta with wheat bran or other diluents. Meta wheat bran bait has proved the most successful, and kills of 8,000 to 12,000 slugs per acre have been recorded.

It was thought desirable to find whether wheat bran could be replaced by other substances of local origin, and therefore more readily obtainable and possibly cheaper, for use as diluents without adversely affecting the effectiveness of the bait. Rice bran and coconut meal were the only substances available at the time for comparison with wheat bran, and a 2 per cent. mixture by weight of Meta with each of these diluents was therefore made up. Actually 16 tablets (approximately 64 gms.) of Meta were crushed to a fine powder and then thoroughly mixed with 8 lbs. of the diluent in each case.

Later corn meal became available and a 2 per cent. mixture by weight of Meta with this diluent was made up. Actually 10 tablets (approximately 40 gms.) of Meta were mixed with 5 lbs. of corn meal, but unfortunately it was not possible to use this bait in any direct comparisons with the baits containing the other diluents.

Rate and Method of Application.

Uniform distribution by broadcasting Meta bait is apparently unnecessary, and the established practice is to moisten the mixture with water and distribute it in small heaps. This method is satisfactory as slugs are capable of moving considerable distances and appear to be attracted to the bait. Other workers have found a successful dosage, using a 2 per cent. mixture by weight of Meta with wheat bran, to be at the rate of 25 lbs. of bait per acre disposed in small heaps a few feet apart, and results in kills of up to 12,000 slugs per acre.

A 3-acre field of sweet potatoes in which slugs were present in great numbers was used for the experiments. In the first experiment 2.4 acres with 66 rows of sweet potatoes were used, and a comparison was made between the effectiveness of Meta bait with wheat bran, rice bran and coconut meal as diluents. This area was divided into 22 plots each of 3 rows. In each plot the first row received Meta bait with wheat bran as diluent, the second bait with rice bran and the third bait with coconut meal. This triple treatment was therefore replicated 22 times through the area. The rate of application was 10 lbs. of bait per acre, 8 lbs. of each bait being actually distributed on 0.8 acre or 22 rows. The bait was moistened with water prior to application until it acquired a crumbly consistency, and was disposed in small heaps in the rows at intervals of about 5 feet. The distribution of 10 lbs. of bait per acre in this way represents about 1,650 heaps of about 1/10 oz. each per acre.

A few of the heaps were covered with empty half-grapefruit peels as a protection against rain, but this was discontinued almost immediately as it appeared somewhat to reduce the effectiveness of the bait and there was no rain. It would appear to be necessary, however, either to protect the heaps from the effects of heavy rain or to repeat the treatment if the heaps are thereby washed away.

In the second experiment 0.5 acre with 14 rows of sweet potatoes was used, and the effectiveness of Meta bait with corn meal as diluent was evaluated. This area was at the north end of the field, where the attack was most severe, complete destruction of the plants necessitating replanting. Due to the severity of the attack no direct comparisons are therefore possible with the results obtained for baits containing other diluents. The rate of application was 10 lbs. of bait per acre, 5 lbs. of bait being actually distributed on 0.5 acre or 14 rows. The bait was disposed in small heaps in the rows as in the previous experiment

Results of Experiments.

The results of the first experiment are given in Table 1 and those of the second experiment in Table 2.

It will be noted that Meta bait, irrespective of the diluent used, was highly effective in attracting and killing large numbers of slugs. On a fairly heavily infested area kills of some 1,800 to 4,800 slugs per acre were obtained in the first 24 hours, depending on the diluent used. Meta wheat bran bait proved to be more effective than Meta baits with either rice bran or coconut meal as diluents. Meta rice bran bait, however, proved to be reasonably effective, while Meta coconut bait was the least effective. On a very heavily infested area a kill of over 13,000 slugs per acre was obtained in the first 24 hours with a Meta corn meal bait.

Table I.—META BAIT AGAINST SLUGS—COMPARISON OF WHEAT BRAN, RICE BRAN AND COCONUT MEAL AS DILUENTS ON FAIRLY HEAVILY INFESTED AREA.

RATE OF APPLICATION—10 lbs. bait per acre.

Bait.	Meta.	Diluent.	Area baited.	Cost of bait per acre.	No. of slugs killed per acre in first 24 hours.	No. of slugs killed per dollar in first 24 hours.
Meta wheat bran ...	16 tablets (64 gms.)	8 lbs.	4/5 acre	78 cents	4,825	6,186
Meta rice bran ...	16 tablets (64 gms.)	8 lbs.	4/5 acre	53 cents	3,724	7,026
Meta coconut meal	16 tablets (64 gms.)	8 lbs.	4/5 acre	68 cents	1,866	2,744

Table II.—META BAIT AGAINST SLUGS—EFFECTIVENESS OF META CORN MEAL BAIT ON VERY HEAVILY INFESTED AREA.

RATE OF APPLICATION—10 lbs. bait per acre.

Bait.	Meta.	Diluent.	Area baited.	Cost of bait per acre.	No. of slugs killed per acre in first 24 hours.	No. of slugs killed per dollar in first 24 hours.
Meta corn meal ...	10 tablets (40 gms.)	5 lbs.	½ acre	78 cents	13,368	17,138

Duration of Toxicity.

Meta passes slowly direct from the solid to the vapour phase. Even at temperatures prevailing under tropical conditions the rate of sublimation is slow, and Meta, therefore, retains its toxicity for an appreciable period. The greatest kill of slugs was invariably noticed on the night following the application of the bait. On subsequent nights, however, further kills were obtained. Usually about 15 to 25 per cent. of the kill obtained on the first night resulted on the second night, and thereafter smaller kills were obtained on successive nights. Under Trinidad conditions Meta bait appears to be effective for about a week, and the treatment should therefore be repeated at about weekly intervals. Two or three applications of bait should normally be adequate to protect rapidly growing young plants from slug attack.

Cost of Treatment.

At the time of the experiment in December, 1939 a box of 20 tablets (80 gms.) of Meta cost 48 cents, wheat bran and corn meal each cost 3 cents per lb., coconut meal cost 2 cents per lb. and rice bran cost ½ cent per lb. Prices quoted are in Trinidad currency ($1.00=4*s.* 2*d.*). Using a 2 per cent. mixture by weight of Meta and a rate of application of 10 lbs. of bait per acre, the cost of treatment varied from 53 to 78 cents per acre, depending on the diluent used. Although Meta wheat bran bait proved to be the more effective, on a basis of cost Meta rice bran bait actually killed more slugs per dollar (*see* Table 1). Labour costs have not been taken into consideration. A boy was found to be capable of baiting an area with Meta bait, resulting in a kill of some thousands of slugs, in the same period of time that hand collection would result in the capture of perhaps a hundred slugs, depending on the skill of the collector.

Recommendations.

The bait recommended for use against slugs in Trinidad, B.W.I. is a 2 per cent. mixture by weight of Meta with rice bran applied in small heaps at the rate of 10 lbs. of bait per acre. Rice bran is recommended as a diluent because it is effective, cheap, of local origin and readily obtainable. Other substances such as wheat bran or corn meal can be used as diluents in place of rice bran without substantially reducing the effectiveness of the bait, but coconut meal is not recommended.

Summary and Conclusions.

1. Meta bait is extremely attractive and toxic to the slug, *Vaginulus langsdorfi* Férussac, but is ineffective against the mole-cricket, *Scapteriscus vicinus* Scudder.

2. A bait consisting of a 2 per cent. mixture by weight of Meta with various diluents applied in small heaps at the rate of 10 lbs. of bait per acre proved effective in killing large numbers of slugs.

3. Meta wheat bran bait proved to be more effective than Meta baits with either rice bran or coconut meal as diluents, although, on a basis of cost, Meta rice bran bait actually killed more slugs per dollar. Meta corn meal bait proved to be effective.

4. Meta bait appears to retain its toxicity for about a week under Trinidad conditions. The cost of treatment varied from 53 to 78 cents per acre, depending on the diluent used.

5. Meta rice bran bait is recommended for use against slugs in Trinidad, B.W.I. on the basis of effectiveness, cheapness, local origin and availability.

Acknowledgment.

I am indebted to Mr. L. J. C. Evans for much assistance in the preparation and application of Meta baits on the College Farm at St. Augustine.

ASSESSMENT OF FERTILITY OF ABNORMAL SOILS.—(A) RENDZINA OR HUMUS-CARBONATE SOIL.

Comparison of Chemical Tests with the Mitscherlich and other Pot Tests.

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(I) Introduction.

Attempts to assess soil fertility by chemical tests, applied either in the laboratory or out-of-doors by means of portable field-kits, are unsatisfactory, unless accurate "limits of adequacy" have been previously established for the methods used, for the soil-types tested, and for the particular crops that are being grown. Such essential preliminary knowledge is gained only by long experience of the field performance of a soil-type in question, aided where possible by the application of the chemical tests to plots comprising manurial experiments laid down within the area occupied by that soil. Thus, to quote an experienced American soil surveyor,† "ninety per cent. of the information "needed to interpret the results (of rapid chemical "soil tests) is obtained from previous knowledge "of the soils and crops, and only ten per cent. "from the test itself".

Chemical soil investigations at the Imperial College of Tropical Agriculture have progressed far enough to have provided reliable numerical standards of comparison or "limits of adequacy" for cacao, for sugar cane, and to a lesser degree for citrus crops growing in Trinidad and certain other parts of the Caribbean Region. These standards have been successfully used for gauging the manurial requirements of the soils commonly utilised for growing these crops, provided the soil-types are "normal" mineral soils derived from sedimentary rocks (sands, silts and clays) containing little or no free lime (calcium carbonate), or soils derived from the more acidic types of igneous rocks. Definite response to manurial treatments based on chemical soil analysis have been obtained, however, only where these soil-types are naturally free-draining by reason of their open porous structure.

Certain soil-types occurring in Trinidad and other parts of the Caribbean Region, must be regarded as "abnormal", in that chemical soil analysis is often misleading when used as the sole guide to their fertility status or manurial requirements. Among these "abnormal" soils is the "humus-carbonate" type, known as *Rendzina*. This soil-type is derived from highly calcareous clays, marls and soft limestones. It usually shows a high degree of saturation by calcium. Another "abnormal" type is ferruginous red soil, rich in reactive hydrous ferric oxide, included in the *Red Earth* and *Terra Rossa* soil-types. Another is fresh mineral sandy soil derived from recently-erupted volcanic "ash", such as occurs in the volcanic islands comprising the Lesser Antilles. Another is highly organic soil, derived from "tropical peat", such as occurs in the pegasse lands of British Guiana, and yet another example is alkali soil containing free sodium hydroxide which imparts an excessively high degree of alkalinity to the soil.

(II) Biological Soil Tests.

The readiest means of approach to a better understanding of the nutrient relationship of such "abnormal" soils, to which conventional chemical testing does not satisfactorily apply, is some form of pot test. This consists in growing an indicator-plant in cultures of the soil to which standard amounts of different nutrients have been added, uniformly packed into suitable containers, and exposed to standard conditions of "climate" (light, temperature and water-supply). The soil sample must be carefully packed so that good drainage and aeration are assured. In the case of sticky clay soils, internal drainage may be greatly improved by appropriately diluting the soil sample with varying amounts of quartz-sand. Diluting with sand also serves in necessary cases to "attenuate" the supply of any particular soil nutrient that it is intended to study, and thus helps to reveal deficiencies.

Among the various pot-tests employed in soil fertility studies is the well-known Mitscherlich test. This has been used for many years in Germany at State-aided stations where farmers may have their soils tested for a small fee. It is also being successfully used in Hawaii as a means of verifying the findings of rapid chemical soil analysis employed for gauging the manurial requirements of sugar-cane soils. The Mitscherlich method has been tried out in somewhat desultory fashion in Trinidad at the College, mainly for the purpose of providing experience for students. The method and the results obtained have already been described in this Journal.* A special pot-test for detecting phosphate shortage in soils by growing tomato seedlings (which are particularly sensitive to deficiency of phosphate) has also been developed at the College.†

* Diploma Course Student, Year II, in charge of Pot Tests.

† G. W. Conrey; *Proc. Soil Sci. Soc. Amer.*, 1936, I, pp. 459-462; quoted by G. V. Jacks, *Imp. Bur. Soil Sci.*, Rothamsted, Monthly Letter, Sept., 1937; *See Tropical Agriculture*, 1938, XV, p. 10.

* Investigations of the Mitscherlich Method in Trinidad. B. de L. Inniss (Foreword by F. Hardy). *Tropical Agriculture*, 1936, XIII, pp. 292-298.

† A Sensitive Pot Test for Phosphate Deficiency in Soils. J. A. McDonald. *Tropical Agriculture*, 1938, XV, pp. 108-111.

(III) The Mitscherlich Pot-Test applied to a Rendzina Soil.

The Mitscherlich method has already been specifically applied at the College for assessing the phosphate requirement of a certain alkaline sugar-cane soil from Antigua,* and in this case, the soil was definitely "abnormal" in that it contained a high proportion of free lime (16.6 per cent. $CaCO_3$) brought up from underlying soft limestone by ploughing. While this Antiguan soil may be described as a "humus-carbonate" type, its disturbance by long-continued cultivation has so mixed humic surface soil with calcareous subsoil that the sample examined cannot be regarded as typical Rendzina. Consequently, it was thought desirable to study a less disturbed example, and for this purpose, material was obtained from the Naparima District of South Trinidad where typical Rendzina occurs over the Princes Town marl belt as mapped by oil geologists. The soil-type is known as *Princes Town Heavy Clay* in Dr. E. M. Chenery's recent classification.†

(IV) Description of the Soil Samples.

Two soil samples from the Princes Town marl belt were examined by the Mitscherlich method; they were :—

(A) *Surface soil* to 9 inches depth; black, granular, humic clay; AB-horizon of deep phase of Princes Town Heavy Clay soil-type, occurring in the Petit Morne section of Cedar Hill Estate of the Ste. Madeleine Sugar Company; Field P.M. 19; sample taken on the flat.

(B) *Subsoil;* grey, powdery marl, CD-horizon of eroded phase of the same soil-type, exposed on a small hill within the same field as the last. The sample was collected to 9 inches depth.

The Rendzina of the Naparima District has been recently described‡ (under the name Hermitage Series) as a "black humous clay "developed over ochreous clay derived from "radiolarian marl". The profile shows a black surface layer, of thickness above 12 inches but variable (depending chiefly on the extent of surface erosion), grading first into bright yellow parent clay (C-horizon), and then into grey or creamy-white, well-bedded, soft marlstone, stained on the fracture planes black with manganese peroxide and orange with hydrous ferric oxide. This horizon also contains irregular patches of calcium carbonate. The black surface layer and the ochreous parent clay do not effervesce with acid, but the marlstone effervesces copiously. It may contain up to 70 per cent. of calcium carbonate, which is chiefly concretionary, since the unweathered, deep-seated, marlstone seldom contains more than 30 per cent. of calcium carbonate. Internal drainage is impeded by the impervious nature of the soil and the parent yellow clay. This soil-type produces excellent crops of sugar cane.

The shallow phase is frequently very calcareous, and sugar canes growing on it are generally chlorotic, but give only small response to nitrogenous manuring. The calcareous nature of the shallow phase probably owes its origin to erosion bringing the calcareous deposits sufficiently near the surface to come within the range of tillage operations.

The Princes Town Rendzina extends eastwards into the cacao-growing district of Rio Claro. Its occurrences there have also been briefly described.§ Near Rio Claro, its erosion is not so evident, but the soil cannot be considered as ideal for cacao, though, on the average, its surface humic black layer is relatively deep (24 inches, as compared with 12 inches. for the sugar-cane Rendzina).

Chemical Features.—The analytical data for the two soil samples are given below, together with those of the Antigua calcareous soil examined in the previous investigation.

Soil Sample	Silt and Clay	Index of Texture I.T.	Reaction Norm.	Reaction Exch.	Calc. Carb. ($CaCO_3$)	Org. Matt.	Total(1) N	C/N Ratio.	Electrical Conductiv. Av. Nutr.	Electrical Conductiv. Rate of Soln.	Av. (2) P_2O_5	Av. (3) K_2O
	%		pH	pH	%	%	%		mhos. × 10^{-6}		p.p.m.	
(A) Surface soil (deep phase) ...	93	42	6.5	5.9	0.0	4.9	0.25	11.3	372	44	75	219
(B) Subsoil (eroded)...	95	39	7.5	7.0	23.6	1.6	0.11	8.3	493	160	11	119
Antigua calcareous soil (for comparison)	71	40	8.0	7.6	16.6	3.0	0.16	11.0	—	—	55	347

(1) Kjeldahl's method. (2) Truog's method; extracting agent, N/500 sulphuric acid.
(3) Exchangeable potash; extracting agent N/2 acetic acid.

* The Phosphate Requirement of Calcareous Soil. F. Hardy, D. M. Hanschell and E. H. Amoroso-Centeno. *Tropical Agriculture*, 1938, XV, pp. 183-186.

† A Provisional Classification of the Soils of Trinidad. F. Hardy. *Tropical Agriculture*, 1940, XVII, pp. 153-158.

‡ A Preliminary Survey of Soil-Types of Sugar Estates of Trinidad. C. F. Charter. *Sugar-Cane Investigation Committee*, 1939, pp. 9-64. The account following is taken mainly from Charter's description.

§ Cacao Soil Surveys: Rio Claro District. F. Hardy and G. Rodrigues. *Fourth Annl. Rept. Cacao Res.* (1934) I.C.T.A., 1935, pp. 51-53.

According to our present standards, *Sample* (*A*) would be described as a slightly-acidic, non-calcareous clay, containing medium-high amounts of organic matter and nitrogen with high carbon-nitrogen ratio. Its content of available phosphate would be considered as medium to medium-high, and well above the limit of adequacy for sugar cane which has been fixed provisionally at 30 p.p.m. for clay-soils. Its content of available potash would be considered as medium-high, and above the border line of adequacy, fixed provisionally at 150 p.p.m. for clay soils. Determination of the exchangeable base status of the surface soil showed it to contain exchangeable calcium to the extent of 70 per cent. of saturation, and nearly 15 per cent. of exchangeable magnesium.

Sample (*B*) would be described as an alkaline, fairly-highly calcareous clay, containing only a low amount of organic matter and medium-low content of nitrogen, with low carbon-nitrogen ratio. Its content of available phosphate would be considered as very low and quite inadequate for sugar cane, and its content of available potash would be considered as low and also inadequate.

(The *Antiguan soil*, by comparison, would be regarded as intermediate between these two, except that its reaction is highly alkaline and its content of available potash very high.) The highly calcareous subsoil and the Antiguan soil are presumed to be practically 100 per cent. saturated by exchangeable calcium.

(V) Experimental Procedure.

The indicator plant used in the Mitscherlich test was Sudan Grass (*Andropogon sorghum*, var. *sudanense*). The soil samples were diluted with pure quartz sand in two of the experimental series, and undiluted in a third series. The proportions of soil to sand were approximately (Expts. 1 and 4) 1 to 5, and (Expts. 2, 5, 7) 1 to 3. The mixtures were carefully worked up with water on a potting bench, the water being added gradually in the form of a fine spray. The object of this important operation was to impart an open crumb structure to the soil so as to ensure proper drainage and aeration. The requisite standard quantities of manures were added in solution during the preparation, together with a small amount of a solution containing all the important "trace" elements needed for complete mineral nutrition. The soil was then transferred to Mitscherlich pots containing a shallow layer of quartz-gravel. Sudan Grass seeds were sown 35 to the pot, and watering was carried out twice a day until the plants had set seed after about 10 weeks' growth. The quantity of water required was gauged from the amount that had collected in the drainage saucers (returned to the soil) and from the feel and appearance of the soil. Facilities for weighing the pots were not available. Rain water was used for watering. The cultures were housed in a steel-framed shed provided with a glass roof and protected at the sides by mosquito netting to exclude birds and insects. The crops were harvested, dried in an oven, and weighed separately. The soils were finally sifted and the root material was likewise dried and weighed. The results obtained are presented in Table I for the following experiments performed on the two soil samples :—

Soil Sample (A)

Princes Town Heavy Clay Rendzina ; Deep Phase

(Black, humic, granular, slightly-acidic clay)

Experiment 1.—Soil : Sand :: 1 : 5

Pot E1	No nitrogen	(P K)
Pots E2, 3, 4	No potash	(N P)
Pots E5, 6, 7	No phosphate	(N K)
Pots E8, 9, 10	Complete nutrients	(N P K)

Experiment 2.—Soil : Sand :: 1 : 3

Pots D1 to 10. (As Expt. 1)

Experiment 3.—Whole soil ; no sand dilution.

Pots F1, 2, 3	No phosphate	(N K)
Pots F4, 5, 6	Complete nutrients	(N P K)

Soil Sample (B)

Princes Town Heavy Clay Rendzina ; Eroded Phase

(Grey, non-humic, powdery, highly calcareous subsoil)

Experiment 4.—Soil : Sand :: 1 : 5

Pots H1 to 10. (As Expt. 1)

Experiment 5.—Soil : Sand :: 1 : 3

Pots G1 to 10. (As Expt. 2)

Experiment 6.—Whole soil ; no sand dilution

Pots J1 to 6. (As Expt. 3)

Experiment 7.—Soil : Sand :: 1 : 3

Pots K1, 2	No phosphate	(N K) (Cpr. Pots G5, 6, 7)
Pots K3, 4	Half phosphate	(N ½P K)
Pots K5, 6	Full phosphate	(N P K) (Cpr. Pots G8, 9, 10)
Pots K7, 8	Double phosphate	(N 2P K)
Pots K9, 10	Treble phosphate	(N 3P K)
Pots K11, 12	Quadruple phosphate	(N 4P K)

Experiment 8.—Whole soil ; no sand dilution

Pots L1 to 12. (As Expt. 7)

Table I.—Experimental Results

Pot Culture Number	1 Treatment	2 Average No. of Plants per pot	3 Average Wt. of Roots (g)	4 Average Wt. of Stems (g)	5 Corrected Wt. of Stems (g)	6 Percentage of Experimental Maximum
Soil Sample (A) : Black humic clay						
Experiment 1. Soil : sand :: 1 : 5					(× 3.32)	
E1	P K	29	2.2	14.5	48.1	21.1
E2, 3, 4	N P	31	7.1	41.6	138.1	60.5
E5, 6, 7	N K	30	5.1	31.8	105.6	46.4
E8, 9, 10	N P K	34	10.7	68.6	227.7	(100)
Experiment 2. Soil : sand :: 1 : 3					(× 2.41)	
D1	P K	32	5.3	17.5	42.2	20.2
D2, 3, 4	N P	29	11.5	59.8	144.1	68.9
D5, 6, 7	N K	30	8.0	49.1	118.3	56.6
D8, 9, 10	N P K	31	13.1	86.7	208.9	(100)
Experiment 3. Whole soil ; no sand addition.						
F1, 2, 3	N K	29	7.6	49.9	(49.9)	79.9
F4, 5, 6	N P K	28	6.9	62.4	(62.4)	(100)
Soil Sample (B) : Grey calcareous subsoil						
Experiment 4. Soil : sand :: 1 : 5					(× 4.00)	
H1	P K	30	2.7	9.5	38.0	11.9
H2, 3, 4	N P	32	15.0	53.9	215.6	67.9
H5, 6, 7	N K	Plants all died		—	—	0.0
H8, 9, 10	N P K	35	15.4	79.3	317.2	(100)
Experiment 5. Soil : sand :: 1 : 3					(× 2.90)	
G1	P K	32	3.3	11.3	32.8	15.5
G2, 3, 4	N P	32	8.4	46.7	135.4	64.3
G5, 6, 7	N K	Plants all died		—	—	0.0
G8, 9, 10	N P K	34	11.3	72.6	210.5	(100)
Experiment 6. Whole soil ; no sand addition						
J1, 2, 3	N K	24	1.3	9.3	(9.3)	11.9
J4, 5, 6	N P K	35	11.2	78.2	(78.2)	(100)
Experiment 7. Soil : sand :: 1 : 3					(× 2.90)	
K1, 2	N K	15	0.8	6.3	18.3	11.6
K3, 4	N ½P K	30	5.7	44.0	127.6	81.0
K5, 6	N P K	33	10.1	54.3	157.5	(100)
K7, 8	N 2P K	29	4.2	39.4	114.3	72.5
K9, 10	N 3P K	32	4.5	36.9	107.0	67.9
K11, 12	N 4P K	30	6.4	47.7	138.3	87.8
Experiment 8. Whole soil ; no sand addition						
L1, 2	N K	27	2.2	14.2	(14.2)	24.5
L3, 4	N ½P K	31	7.1	52.8	(52.8)	91.0
L5, 6	N P K	32	6.9	58.0	(58.0)	(100)
L7, 8	N 2P K	32	5.0	44.3	(44.3)	76.4
L9, 10	N 3P K	32	9.8	66.8	(66.8)	115.2
L11, 12	N 4P K	30	8.2	63.4	(63.4)	109.3

Table II.—Nutrient Status and Manurial Requirements

(Calculated from Experimental Results)

Nutrient	Nutrient Contents						Manurial Requirements	
	Calculated from Mitscherlich Data for Cultures of :—				Expressed as parts per million 6-ins. layer	Determined by chemical methods	Calculated from Mitscherlich Data	
	Whole soil	Soil : sand 1 : 3	Soil : sand 1 : 5	Mean			Nutrients	Standard Manures
	Hundredweights (cwt.) acre				Parts per million		Cwt. per acre	
	Soil Sample (A) : Black humic clay							
Nitrogen (N)	—	0.97	1.41	1.19	67	—	3.61	S/A 18.0
Phosphate (P_2O_5)	0.93	1.16	1.19	1.09	61	75	0.66	Super 3.7
Potash (K_2O)	—	1.05	1.15	1.10	62	219	0.50	S/Pot 1.0
	Soil Sample (B) : Grey calcareous subsoil							
Nitrogen (N)	—	0.87	0.90	0.88	49	—	3.92	S/A 19.6
Phosphate (P_2O_5)	0.07 0.17	0.21	—	0.16	9	11	1.59	Super 8.8
Potash (K_2O)	—	1.11	1.69	1.40	78	119	0.20	S/Pot 0.4

(VI) Discussion of Results.

Sample (A) : Black Humic Clay.

The pot yield data for dry stem material (Table I : Column 5) show good agreement for the soil-sand mixtures, but not for the whole soil which gave much lesser yields attributed to early damage by cut-worms.* Expressed as percentages of the yields obtained with complete manure (N P K), the data clearly demonstrate the relative efficacy of the different nutrients.

Nitrogen: The most striking indication is a *marked deficiency of available nitrogen* in the Princes Town Rendzina soil, in spite of the fact that it contains, according to chemical analysis, a fairly large amount of *total nitrogen* (0.25 per cent.).† In the absence of nitrogenous manure, but when abundant phosphate and potash were present, the yield was only about 20 per cent. of the maximum.

* *Note.*—The factors used for "correcting" the yields given by the soil-sand mixtures are based on the actual degrees of dilution of the soil by inert sand that were employed in the different experiments. This is the routine procedure prescribed by Mitscherlich.

In the case of heavy sticky clays, dilution with sand generally alters their physical condition, improving their aeration and drainage considerably. This frequently results in increased yields, as would appear to be the case for the black humic clay, though actually the damage from cut-worms which the plants of the whole-soil cultures sustained may chiefly account for their retarded growth.

† This unexpected result accords with laboratory data for nitrate contents of untreated soil before and after incubation at half-saturation moisture content for 4 weeks, which gave values for this soil of 1.6 and 1.7 p.p.m. nitrate-N, which are exceptionally low.

Application of the Mitscherlich equation for nitrogen shows that, theoretically, the yield of Sudan Grass in the absence of nitrogenous manure would only be about 14 per cent. of the maximum possible with unlimited nitrogenous manure. This large deficiency of *available* nitrogen in a soil which would be considered by ordinary standards as rich in nitrogen seems to be a characteristic feature of Rendzina soil, and, in such sense, this soil-type may be regarded as "abnormal".

Calculation from Mitscherlich formulae for determining nutrient contents and manurial requirements (Table II) gives the values 1.19 cwt. per acre for available nitrogen content, and 3.61 cwt. per acre for manurial requirement, equivalent to about 18 cwt. per acre of sulphate of ammonia, which is the dressing that would be recommended by Mitscherlich for raising the fertility status of this soil to optimum.

Phosphate: The nutrient next in order of deficiency is evidently phosphate. In the absence of phosphate manure, the yield of Sudan Grass was only about half the yield with complete manure. According to the Truog test, the soil would be regarded as well supplied with available phosphate (75 p.p.m. as against 30 p.p.m. considered adequate in sugar-cane soils). Apparently the high calcium status of Rendzina is associated with a high degree of solubility in the Truog extracting agent of its phosphatic component. In this respect also, the soil-type would be regarded as abnormal, unless the phosphate requirement of Sudan Grass is actually very much greater than that of other plants, such as sugar cane, which is doubtful in view of general experience with that indicator plant.

RESULTS OF MITSCHERLICH TEST APPLIED TO PRINCES TOWN HEAVY CLAY RENDZINA: TRINIDAD.

FIG. 1.—*Expt.* 1.—Black clay topsoil; soil : sand : : 1 : 5.

Left to right.—Lacking N; lacking K; lacking P; Complete manure.

Sudan Grass cultures, 6 weeks old (E1, E2, E5, E9).

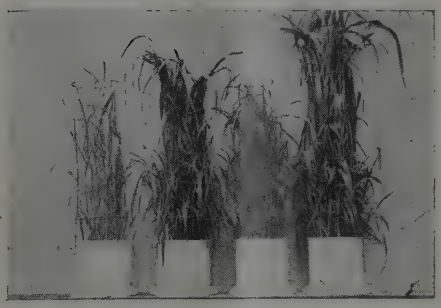

FIG. 2.—*Expt.* 2.—Black clay topsoil; soil : sand : : 1 : 3.

Left to right.—Lacking N; lacking K; lacking P; Complete manure.

Sudan Grass cultures, 6 weeks old (D1, D3, D5, D8).

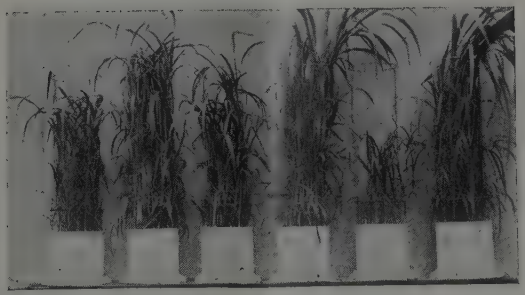

FIG. 3.—*Expts.* 1, 2, 3.—Black clay topsoil; Lacking P *v.* Complete manure.

Left to right.—Whole soil; soil : sand : : 1 : 3; soil : sand : : 1 : 5.

Sudan Grass cultures, 6 weeks old (D2, 4; D5, 10; E5, 9).

RESULTS OF MITSCHERLICH TEST APPLIED TO PRINCES TOWN HEAVY CLAY RENDZINA: TRINIDAD.

FIG. 4.—*Expt.* 4.—Grey calcareous subsoil ; soil : sand : : 1 : 5.

Left to right.—Lacking N ; lacking K ; lacking P ; Complete manure. Sudan Grass cultures, 5 weeks old (H1, H4, H5, H8).

FIG. 5.—*Expt.* 5.—Grey calcareous subsoil ; soil : sand : : 1 : 3.

Left to right.—Lacking N ; lacking K ; lacking P ; Complete manure. Sudan Grass cultures, 5 weeks old (G1, G4, G5, G10).

FIG. 6.—*Expt.* 6.—Grey calcareous subsoil ; whole soil (no sand).

Left to right.—Lacking P ;—3 pots ; Complete manure ;—3 pots. Sudan Grass cultures, 5 weeks old (J1, 2, 3, J4, 5, 6).

Calculation from the Mitscherlich formula (Table II) gives the mean available phosphate content as 1.94 cwt. per acre P_2O_5, denoting a deficiency of 0.66 cwt. per acre, which could be made good by a dressing of 3.7 cwt. per acre of superphosphate. Actually, the addition of phosphate may be expected greatly to increase the yield due to nitrogenous manuring; in the pot tests, the two together (N P) gave 65 per cent. of the yield of Sudan Grass obtained with complete manure.

Potash: The least deficient nutrient in the Princes Town Rendzina seems to be potash. In the absence of potash manure, the yield of Sudan Grass was 65 per cent. of that given by complete manure. Chemical analysis, according to our present standards of adequacy, showed a fairly high content of available potash (219 p.p.m. exchangeable K_2O per acre 6 ins.). Our present laboratory standard would appear, however, to be too high, at least for sugar cane growing on the various *non-calcareous* soil-types that occupy the majority of the sugar estates of Trinidad. For these non-calcareous soils, P. E. Turner* sets the value 90 p.p.m. exchangeable potash (K_2O) as connoting unresponsiveness to potash manures. On the other hand, an entirely different standard may be required for assessing potash adequacy for *calcareous* soils and soils containing a high degree of saturation by exchangeable lime, in which case our present standard, gauged by the results of the Mitscherlich test with Sudan Grass, would seem actually to be too low. The discrepancy could also be explained by assuming that Sudan Grass possesses an unusually high potash requirement, but, according to results obtained by Hawaiian authorities,† such a presumption seems unwarranted. Indeed, general experience with this indicator plant suggests that its potash requirement for satisfactory growth is relatively low. The conclusion that lime-saturated Rendzina soils show abnormality in their potash relationships, as gauged by conventional chemical tests, would thus appear to be established.

Calculation from the Mitscherlich formula (Table II) gives the mean available potash content of the Princes Town Rendzina as 1.10 cwt. per acre K_2O,‡ implying a deficiency of 0.5 cwt. per acre, which could be made good by a dressing of 1 cwt. per acre of sulphate of potash.

* Field Experiments on Sugar Cane in Trinidad: *Annual Report for* 1940. P. E. Turner, Trinidad Dept. Agric., Sugar-Cane Investigation Committee Publication, March, 1941: p. 243.

† R. J. Borden, Hawaiian Sugar Planters' Association—private communication.

‡ Mitscherlich tests as applied in Hawaii, indicate 1.57 cwt. per acre K2O content (1 : 3 :: soil : sand) as denoting a potash-deficient sugar-cane soil, and 2.90 cwt. per acre K2O as denoting one which will not respond to potash manuring.

SAMPLE (B): GREY CALCAREOUS SUBSOIL.

The pot yield data in Table I (*Expts.* 4 *to* 8), except for the whole soil, show fair consistency. As before, the plants comprising the whole soil cultures were severely damaged by cut-worms. The chief deficiency obviously is nitrogen, o which the subsoil contains only a small total amount, but the most strikingly deficient nutrient is available phosphate. In the absence of phosphatic manure, most of the plants died after they had grown about three inches high.

Nitrogen: In the absence of nitrogenous manure, the yield was only about 14 per cent. of that of the completely manured cultures, and less than 9 per cent. of the theoretical maximum with unlimited nitrogen. The nitrogen deficiency, according to Mitscherlich standards (Table II), could be made good by the addition of about 20 cwt. per acre of sulphate of ammonia, which is a very large dressing for practical purposes.

Phosphate: The case of phosphate was specially investigated by Expts. 7 and 8, in which increasing doses of phosphate manure were added to a series of cultures to find whether or no the calcareous subsoil is capable of fixing phosphate appreciably. The yield data (Table I) show that the subsoil is not a phosphate fixer; there appears to be no need for phosphate additions greater in magnitude than the standard Mitscherlich dressing, and even one-half of that amount gives yields between 80 and 90 per cent. of the yield of the fully-manured subsoil.

The Truog test showed the subsoil to contain only a very small amount of available phosphate, and the result coincides closely with the findings from the pot tests.

Calculations from the yield data (Table II) show a high degree of phosphate deficiency, which could be made good only by large dressing of superphosphate manure (of the order of 9 cwt. per acre), although smaller dressings than this might still be effective, provided abundant nitrogen was also added.

Potash: Evidently potash is not very deficient in the subsoil, which, according to the yield data, contains a considerably greater amount of available potash than the surface soil. This difference is not shown by the chemical test, in which acetic acid is used as extracting agent, nor would reliability be expected, since a proportion of the extracting acid must always be neutralised by free calcium carbonate present in the subsoil (24 per cent.). The method employed for estimating available potash would obviously be assumed to fail under such circumstances.

The manurial requirement for potash, calculated from the Mitscherlich formula (Table II), is equivalent to only 45 lb. per acre of sulphate of potash, which is a negligible amount.

(VII) Comparison of Experimental Results with Estate Manurial Experience and Practice.

The response to manuring the Princes Town Heavy Clay Rendzina has been investigated in the Naparima District by numerous field experiments laid down on the sugar-cane lands of the Ste. Madeleine Company, as well as by a few experiments on cacao estates in the Rio Claro area.

Sugar Cane: The results of sugar-cane experiments carried out on this soil-type, under the charge and direction of J. A. Potter, in collaboration with the Sugar-Cane Investigation Committee, have been published by P. E. Turner, in a series of articles and reports.* The following relevant abstracts indicate some of the main findings. It should be noted that the areas on which the manurial experiments were laid down show variable thickness of black humic soil, owing to differing degrees of erosion, dependant on the angle of slope of the land, so that somewhat erratic results may be expected.

Concerning *nitrogen*, Turner writes:—(*ibid.* (*b*) Report for 1940, p. 238), "On a shallow phase "(of Princes Town Heavy Clay), a first-season "dressing of 3 cwt. sulphate of ammonia, without "a second-season dressing, was found inadequate "for maximum yield of (Uba) plant cane and "sugar. A dressing of 3 cwt. to the ratoon crop "gave maximum yield of sugar but not of cane".

In view of the results obtained in the Mitscherlich pot-tests, the smallness of the increases obtained on this eroded phase of the Princes Town Rendzina would not be unexpected, particularly considering that phosphate and potash were not included in the treatments applied in this experiment.

Manurial experiments involving phosphate and potash, described in P. E. Turner's Report for 1940, included a basal dressing of 70 lb. of nitrogen, but no graded amounts of nitrogen greater than this were applied.

The results of two separate experiments are considered as comprising five different categories; the following abstracts indicate the main conclusions reached regarding phosphate and potash interactions.

(*a*) "Treatment with phosphate led to improve-"ment in the quality of a plant crop and to "large gain in yield of plant sugar in the "presence of potash, and to fall in crop "quality and only small gain in yield of "plant sugar in its absence. On a second "area, this interaction of phosphate with "potash was not found to obtain". (*ibid.* p. 246.)

(*b*) "The beneficial effect of potash on quality "of the plant crop and on the yield of plant "sugar was found to increase greatly with "increase in size of dressing of phosphate". (*ibid.* p. 241).

The experimental results from which these conclusions are drawn show greatest increase for a dressing of 40 lb. per acre of phosphate (P_2O_5), combined with 100 lb. per acre of potash (K_2O), superimposed on the basal dressing of 70 lb. of nitrogen. The yields of plots that received only nitrogen were 35.25 and 35.88 tons plant cane per acre, and the greatest increases in yield through manuring with phosphate and potash were 18.2 and 17.8 per cent. respectively in the two experiments. The amounts of phosphate, potash and nitrogen that were used are equivalent to dressings of 2 cwt. per acre of superphosphate, 2 cwt. per acre of sulphate of potash and 3 cwt. per acre of sulphate of ammonia. Appreciable increases in yield of 13.4 and 7.4 per cent. were also given by a dressing of 2 cwt. per acre of superphosphate in the absence of potash manure.

The results of these and other manurial experiments carried out on Princes Town Rendzina growing sugar cane in the Ste. Madeleine Estates have warranted the following general statements: *

(*a*) Applications of sulphate of ammonia alone in dressings of 5, 10 and 15 cwt. per acre have given responses with plant canes and 1st ratoons on areas presenting both deep and eroded phases of this soil-type. Although significant increases in yield were obtained in each case (especially with ratoons), the additional yields given by dressings exceeding 5 cwt. per acre were small and insignificant. On the eroded phase, the response to nitrogen was transitory and soon disappeared.

(*b*) Phosphate, applied as a very large dressing of superphosphate (35.3 cwt. per acre) gave only a small increase in yield (5 tons cane per acre, say about 10 per cent.) when used alone, but it gave a greatly increased yield (15 tons cane per acre or 30 per cent.) when combined with a dressing of sulphate of ammonia, 6.25 cwt. per acre (or 140 lb. nitrogen). The further addition of potash manure usually produced no more increase.

(*c*) Sugar cane growing on the *eroded* phase of the Princes Town Rendzina responded to mixed manure consisting of 3 or 6 cwt. sulphate of ammonia, 1½ cwt. superphosphate and 2 cwt. sulphate of potash per acre.

Cacao: The Princes Town Rendzina growing cacao in the Rio Claro District of South Trinidad responds only to soluble phosphatic manures.† Nitrogenous manures confer no benefit, neither when applied alone nor in combination with other

* (*a*) *Tropical Agriculture*; XII, 1935, pp. 320-332; XIII, 1936, pp. 38-47; XIV, 1937, pp. 150-155; *ibid*, pp. 179-188; XVII, 1940, pp. 208-212.

(*b*) Annual Reports on Field Experiments on Sugar Cane in Trinidad, *Sugar-Cane Investigation Committee*, Years 1938, 1939, 1940.

* J. A. Potter, private communication.

† Manurial Experiments on Cacao in Trinidad and Tobago. F. J. Pound. (Submitted, 1938; published 1940), p. 5.

manures;* indeed they tend to nullify much of the benefit due to phosphate. Potash manures seldom exert any effect on cacao yields on this soil-type. The most profitable manurial treatment is 6 cwt. per acre (or 2 lb. per tree) of superphosphate, followed by annual dressings of about 2 cwt. per acre. In an experiment, this treatment has given an average yearly increase of 36 per cent. of dry cacao for soil normally yielding about 470 lb. per acre.

(VIII) Summary.

1. A black clay "humus-carbonate", or Rendzina soil and its grey calcareous subsoil have been tested by chemical laboratory methods, and by the application of the standard Mitscherlich pot test, in order to assess their fertility as a guide to manuring.

This soil-type occurs as an east to west belt across the Naparima District of South Trinidad, where it has been named the *Princes Town Heavy Clay*.† It is there mainly planted to sugar cane (Ste. Madeleine Estates) and to cacao (Rio Claro District). The Rendzina Intrazonal soil-group, derived from marls, is widespread in the Caribbean region, and may be regarded as "abnormal", in that provisional "limits of adequacy" employed for interpreting the results of chemical analyses of a wide range of Caribbean soil-types, derived from sedimentary rocks and some igneous and metamorphic rocks, do not strictly apply to Rendzina, presumably because of its high calcium status and the great stability of its peculiar black humic component.

2. Chemical analysis of the Rendzina *surface* soil sample, interpreted by our present standards, indicated that it contained a medium-high amount of nitrogen, a medium-high and adequate amount of available phosphate (Truog test), and a medium amount of available (exchangeable) potash, above the border line of adequacy. The Mitscherlich pot test, however, showed it to be markedly deficient in available nitrogen, distinctly deficient in available phosphate and slightly deficient in available potash.

3. Chemical analysis of the grey calcareous Rendzina *subsoil* sample indicated that it contained a medium-low amount of nitrogen, a medium (inadequate) amount of available phosphate, and a low (inadequate) amount of available potash. The Mitscherlich pot test showed the sub-soil to be extremely deficient in available nitrogen, particularly deficient in available phosphate, and only very slightly deficient in available potash.

4. Yield-data from field manurial experiments on Princes Town Rendzina growing sugar cane within the Ste. Madeleine Estates, and cacao within the Rio Claro District, have been discussed, and the main conclusions drawn from them summarised. While the interactions between nitrogen, phosphate and potash applied in the manuring of *sugar cane* have not yet been fully explored, it is evident that greatest response is given by nitrogenous manure only when phosphate, and in some cases, potash manures, are applied in addition. The optimum dressings have not yet been worked out.

For *cacao*, soluble phosphatic manures alone have given responses; nitrogenous manures have generally exerted deleterious effects, and potash manures so far have conferred no benefit.

5. The indications of the results of this investigation are :—

(*A*) *Manuring Sugar Cane.*

(*a*) The Princes Town Rendzina, growing sugar cane, should benefit from large dressings of nitrogenous manure (*e.g.* of the theoretical order of 18 to 20 cwt. per acre of sulphate of ammonia), but that this manure should invariably be combined with fairly large dressings of phosphatic manure (*e.g.* theoretically, 3½ to 9 cwt. per acre of superphosphate) for maximum returns. Further benefit should also follow the additional application of small dressings of potassic manure (*e.g.* theoretically, ½ to 1 cwt. per acre of sulphate of potash).

(*b*) Where the grey calcareous subsoil is exposed by erosion, the need for phosphate when nitrogenous manures are applied is imperative.

(*c*) Optimal practical or economic dressings of suitable manurial mixtures could only be decided by field experiments laid down both on deep and on eroded phases of the Rendzina; profitable manurial dressings would doubtless be much lesser in magnitude than the theoretical quantities derived by calculation from the Mitscherlich formulae.

(*B*) *Manuring Cacao.*

For high production of cacao, nitrogen is presumably not so important as phosphate and potash, and the results of the pot test agree with those of field experiments in that both indicate an essential need for phosphate, and a negligible potash requirement of the deep phase of the Princes Town Rendzina. Shallow or eroded phases of the soil-type might respond to nitrogenous manure applied in addition to phosphate.

(IX) Recommendations.

(*a*) In designing further field experiments on the deep and on the eroded phases of the Princes Town Rendzina growing sugar cane, the interactions between graded dosages of nitrogenous and phosphatic manures might be further investigated. For example, experimental dressings of 5, 10 and 15 cwt. per acre of sulphate of ammonia might be combined in all possible ways with dressings of 2, 5 and 8 cwt. per acre of superphosphate. A basal or half-plot treatment with potash manure (for example one cwt. per acre of sulphate of potash) might be applied, particularly where chemical soil analysis has revealed a low content of available potash.

* *Ninth Annual Report on Cacao Research*, 1939, I.C.T.A., 1940 (Summary of Results for 1939). F. Hardy, p. 30.

† Equivalent in part to the Hermitage Series of C. F. Charter.

MODERN SOIL CLASSIFICATION AND MAPPING

With Special Reference to Tropical Soils

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[*The following article is based mainly on Part V of the* 1938 *Yearbook of the United States Department of Agriculture* (" *Soils and Men* "), *pages* 1019 *to* 1161. *The second part, which especially concerns tropical soils that were studied and mapped by American surveyors in Puerto Rico and Hawaii, has already appeared in print in the Geographical Review*; *July*, 1939, *published by the American Geographical Society of New York.*—Editor]

Part I—The Basis of Modern Soil Classification

(1) *Why Soils should be studied and Mapped*—" The general objective of soil research is to " determine the kind, yield and quality of plants " that can be produced under alternative systems " of management on various types of soil " ; this being so, then there is obvious need for a full description and for accurate delineation on maps of each of the main soil-types that occur in any country if the land is to be utilised to its full capacity. Thus, it is estimated that the soils occurring within some 1½ million square miles of the continental United States eventually need to be mapped in detail. Subsequent to the initiation of the United States soil survey some 40 years ago, more than two-thirds of this task has already been accomplished, and in addition, soil surveys have been completed in Puerto Rico, the Virgin Islands, Hawaii, the Panama Canal Zone and parts of Alaska.

The investigations have established the existence of several thousand soil-types, but the detailed pattern of these can be adequately depicted only on maps drawn to very large scale. By merging together several types into geographical associations, generalised small-scale soil maps may be constructed, and these have considerable significance and utility in the development of agricultural communities, though they may have little value in relation to land usage within individual farms. A map of this sort, on the scale of 1 inch to 120 miles, showing the distribution of the chief soil associations of the United States and of the dependencies named above, is appended to the Yearbook of Agriculture for the year 1938 (*Soils and Men*). Altogether, 161 different soil associations are shown, each by a distinctive colour and symbol, and of these, 132 associations occur within the continental region of the United States. In the text, each soil association is described with respect to its geography, the climate of the area occupied by it, the native vegetation, the kind of parent rocks and their weathered material from which the soils were derived, the main features of the individual soils comprising the association, and lastly, their use for crop production. Several photographic illustrations, showing characteristic landscapes, add to the interest of the descriptive section.

(2) *Soil Classification*—The classifying and naming of soils are problems that have exercised the ingenuity of soil scientists (or pedologists, to give them their preferred title) for more than half a century, and even now no general consensus of opinion has been reached as to the most satisfactory basis and the least ambiguous rules that should be employed in the identification, naming and grouping of soil-types. It is common knowledge that soils usually merge, when traced downwards, into solid rock, and that the changes which rocks undergo when transformed into soil by the aid of growing plants depend very largely on the operation of such factors of climate as rainfall and heat. It is therefore to be expected that both the nature of the parent rock and the sort of climate that prevails should figure conspicuously in systems of soil classification. Thus, in the descriptions of the soils of the United States set out in the 1938 Yearbook, soil associations are subdivided into soil groups, depending on a general similarity in the range of geologic, biologic and climatic factors that have operated to produce them. In all, 24 different soil groups are differentiated in the text and in the legend of the soil map.

(3) *The Significance of Soil Colour*—The names of the soil-groups, it may be noticed, frequently include some *colour category* such as red, brown, reddish-brown, yellow and grey, indicating that one result, at least, of the operation of soil-forming processes is the liberation of *iron oxide* from combination in certain of the rock minerals, and its differential oxidation and hydration into end-products of which the various yellow, brown and red " ochres " and " rouge " are examples. In the warmer parts of the United States and in the tropical dependencies, it will be noticed that soil groups described as " red " most frequently occur; this is because the particular form of residual iron oxide which is produced by mineral decay under hot conditions and alternating wet and dry seasons happens to be coloured bright red, as indicated by its name, " haematite ". Red soils occur over most of the South-Eastern States and in parts of Puerto Rico and Hawaii, and throughout the Canal Zone. At the other extreme, the particular kind of iron oxide formed under cool and moist conditions is yellow-brown in colour; this is called " limonite ",

a term derived from a German word for meadow. Yellow-brown soils are widespread in the New England States and also over a vast area in the western part of the Great Plains region. Another form of iron oxide, imparting a chestnut-brown colour to soil, is produced under medium-hot and medium-dry conditions, such as obtain in the northern part of the Great Plains. Finally, wherever the oxidation of the residual iron compounds in soil is prevented, as for example when the soil is waterlogged, and often when it contains abundant organic matter, the colouration may be dull grey or blue, and quite devoid of warm tints. A great excess of decayed organic matter, such as occurs in Bog Soils or in Prairie Soils that have long supported a luxurious grassy vegetation, in any case would impart a jet-black colour to the soil, thus giving yet other groups.

Although soil colour figures prominently in all schemes of soil classification, in itself it has no particular significance. Nevertheless, it serves as a valuable *index of conditions which control plant growth*, and which bring about the formation of particular sorts of soils. For this reason, soil colour provides a useful basis for field diagnosis and mapping.

(4) *The Role of Water in Soil Formation*—The most influential agent that changes rocks into soils, both by chemical means and by fostering plant-growth, is *water* falling as rain. Not only are rock-minerals profoundly altered by it, so that inert residues (such as kaolin, quartz and iron oxides) are finally left, but the bases liberated during the breakdown (namely, lime, potash, soda and magnesia) are leached out and eventually carried away in solution to rivers and the sea. This leaching process operates from the surface downwards, so that the mass of altered rock gradually becomes differentiated, the surface layer being the first to be depleted of bases. On top of this surface layer, the remains of dead plants accumulate, and by degrees the more soluble products of their decay may penetrate into the weathered rock material below, causing a darkening of colour. Viewed in section, the soil will now show a marked stratification, and its *profile* may be subdivided into three main horizons, namely (A) the soil proper, consisting of more-or-less acidic, leached mineral matter, containing humus in its upper part, (B) an underlying layer of less acidic rock residues within which some of the soluble substances from the layer above have been deposited, and (C) the altered or weathered parent rock material, derived from the solid rock itself.

(5) *Podsols*—In extremely wet temperate regions, the stratification of the soil profile is usually very distinct and striking, since downward leaching is here very intense. The uppermost black humic layer, with its thick deposit of leaf litter, is sharply underlain by a leached and bleached grey layer of inert mineral residues (mostly quartz), and this in turn by an iron-stained brown layer of accumulation that may even be sealed up to form a hard-pan. Soils displaying a profile like this were named long ago by Russian investigators, *podsol* (meaning ashlike), and the process, dependant on heavy leaching by rain, that gives rise to them, was called *podsolisation*. In the United States soil map, five out of the 24 groups of soil associations are labelled Podsols. Three of these (Grey, Brown and Grey-Brown Podsols) occur in the North-eastern States, around the Great Lakes, and in Alaska, where they are mostly derived from granite or granitic glacial material. One group (Ground-Water Podsol) occurs in the low-lying south-easterly coastal fringe where drainage is imperfect. The remaining two are derived from red and yellow rock-weathering products (often termed "laterite") occurring in the very hot, humid South-eastern States, as well as in the wetter parts of tropical Puerto Rico. As would be expected, soils of the Podsol groups are highly acidic and lacking in lime, potash and other nutrients; they support natural forest growths, and need heavy liming and manuring when utilised for agriculture.

(6) *Prairie Soils and Tschernozem*—Where the rainfall is of lesser magnitude, and the natural vegetation is tall grass, leaching is insufficient to deplete the surface soil of bases, and in addition, a large amount of black organic matter tends to accumulate. In the drier regions, lime is carried down as far as the B-horizon and there deposited as white carbonate concretions. This soil closely resembles the Black Earth (Tschernozem) of the Russian Steppes. In the somewhat wetter prairie land of the highly-fertile Corn Belt, no lime accumulations are present within the profile, though the soil has not been leached sufficiently to render it acidic.

(7) *Chestnut Soils*—In the still drier regions further west (for example, the northern Great Plains), dark red-brown soils, showing grey or white calcareous B-horizons at about the 1½-foot depth, have been developed under a mixed short and tall grass vegetation. These soils form a large part of the Spring Wheat belt, and are highly productive when their moisture supply is adequate. They are continued southwards, as Reddish Chestnut Soils, through the warmer States of Oklahoma and Texas to the Gulf of Mexico, where they are utilised for raising livestock. Unfortunately, some of these soils are subject to severe wind-erosion where and when the grass cover is destroyed through over-grazing. Other sorts, called Brown Soils and Reddish-Brown Soils, occur in the western part of the Great Plains and in the intermontane country of the far West, where the climate is cooler, though still semi-arid. They are continued south-westward into Arizona; they also show lime accumulations at variable depth; and are highly fertile, especially when irrigated.

(8) *Desert Soils*—The extreme expression of climatic soils is the desert. In the United States, grey desert occupies vast areas in the western intermontane region, where the climate ranges from cool-temperate to warm-arid, and the vegetation is mainly sage-brush. Some areas of soils (called Solonchak and Solonetz) are too salty or alkaline for agriculture, unless specially treated and carefully irrigated. Red Desert occurs in the South-western States from Texas to Southern California, where the climate is still hotter and drier. As would be expected, Desert Soils show no marked profile differentiation, because downward leaching does not occur.

(9) *Lithosols*—The soil-groups so far described occur mainly on undulating plains land where it is possible for a definite deep soil profile to develop. On steeply-sloping mountainous land, however, erosion removes the products of rock weathering as fast as they are formed, so that the soil is always immature or skeletal, and thin or stony. Soils of this sort are consequently called Lithosols; three sub-groups are distinguished on the soil map, namely, Humid Lithosol, Arid-Subhumid Lithosol and Unvegetated Lithosol. The humid kind is heavily timbered, and covers a wide geographical range. The arid kind carries a grass or bush vegetation, and is very variable, while the third kind, occurring mainly in the Western States, consists of unforested stony land, broken land and lava beds, and has no agricultural value. Lithosols owe their distinguishing features to topography and not to climate; consequently they are placed in the Azonal Class.

The only other important soil groups differentiated on the map are Rendzina (soils formed from highly calcareous marls), Planosols (badly-drained plateau soils having claypans, not included among Podsols), Non-Calcic Brown Soils, Bog Soils and Half-Bog Soils, Dry Dune Sands and Alluvial Soils. The last-named mainly occupy the great Mississippi Valley and other large river valleys in the United States, but small expanses are very widespread in all parts of the country. None of these soil-groups, however, is a Zonal group (that is one whose soils show profile features produced by the operation of climatic agencies); some show the domination of the parent rock as a factor in soil differentiation, while others show the influence of topography.

Part II — The Soils of Puerto Rico and Hawaii

Much of the information about the soils of Puerto Rico and the Hawaiian Islands contained in the 1938 Yearbook is quite new, never having been published before. It has especial interest to students of tropical agriculture, in that it constitutes an attempt to classify little-known soils of widespread occurrence in the humid torrid zone. The most striking feature of both areas is the great diversity of climate (especially rainfall), and its rapid variation over small distances. Thus, Puerto Rico is only 3,350 square miles in area, yet its annual rainfall varies from 120 inches in the central highlands above 2,000 feet, to less than 25 inches along the southern coastal strip. Similarly, Hawaii, area 4,000 square miles, has a rainfall ranging from 100 to 500 inches on the windward slopes between the 5,000 and the 300 feet contours, while the lower leeward slopes receive less than 20 inches. Almost identical conditions obtain in each of the other seven islands of the Hawaiian group which together have an area of 2,400 square miles and show altitudes up to 14,000 feet. Above the cloud belt, at 6,000 feet, the rainfall diminishes rapidly. The mean temperature in Hawaii varies from 75°F. at Honolulu to near freezing at the highest elevations.

The soil-forming rocks in Puerto Rico comprise a wide range of types, including volcanic agglomerates, "ashes" and dust, as well as igneous intrusions and lavas (representing the remnants of four ancient volcanoes). In addition, there are also hard limestones, soft marls and abundant sandy deposits originally laid down in the sea. On the other hand, the soil-forming rocks of the Hawaiian Islands comprise mainly volcanic "cinders", "ashes" and basaltic lava. The combination of highly variable climatic and geologic factors in Puerto Rico have given rise to a very intricate soil pattern; some 364 soil-types have been recognised and included in 200 soil-series, but only 11 soil associations are described and mapped in the Yearbook, being classified into 7 groups, of which three are zonal or climatic. The Puerto Rican zonal groups are called (1) Red and Yellow Podsolic Soils, (2) Yellow and Red-Brown Lateritic Soils, and (3) Reddish Chestnut Soils. The last-named is the equivalent of the semi-arid Reddish Chestnut Soils of the grassy plains of western Oklahoma and Texas, and has developed from shaley limestones, tuffs or alluvium occurring within the Southern Coastal Plain of Puerto Rico where the annual rainfall is less than 45 inches. One of the others also resembles, and is nearly equivalent to, another continental zonal soil, namely, Red and Yellow Podsolic Soil, which has many features in common with the red soils of the Southern States. It occurs in the interior uplands of the Island where the rainfall ranges from 160 to 75 inches, and has been derived mostly from fragmental volcanic rocks (andesitic agglomerate and "ash," with some lava). It originally supported luxuriant tropical rain-forest, but much of it has been planted in citrus fruits, pineapple, banana and coffee. The soil is typically an acidic granular clay, showing little profile differentiation.

The third soil group (Lateritic Soils) has no real counterpart anywhere in the United States, though it is represented in many of the mountainous West Indian Islands comprising the Antillean Volcanic Arc, as well as in the Hawaiian

Islands. It has been formed under high rainfall (80 to 100 inches a year) alternating with dry season conditions. The parent rock is either a basic volcanic lava (such as serpentine in Puerto Rico or basalt in Hawaii), or impure hard limestone containing contemporaneous impurities such as volcanic "ash" or dust. In all cases, the rock is profoundly altered into a thick crumbly kaolinic residue, stained bright red with iron oxide (haematite), and occasionally containing free alumina (gibbsite). Such material is usually described as "*lateritic*". Most of the bases have been leached out, and the soil is consequently very infertile, needing heavy manuring when brought into agricultural production from virgin forest. On the other hand, it possesses a remarkable crumb structure which enables it to be ploughed and cultivated immediately after heavy rains.

The most widespread type of soil, both in Puerto Rico and in the Hawaiian Islands, is Lithosol, which comprises an Azonal group having no very definite morphology, and consisting chiefly of partly-weathered rock fragments. It occupies steeply-sloping ground; it is very shallow and generally not suitable for large-scale cropping, except to pasture grasses, though Puerto Rican peasants utilise it for growing high-quality tobacco and shallow-rooted subsistence crops. In the Hawaiian Islands, Lithosol, overlying volcanic "ash" and lava, is either still in virgin forest, or has been laid down to pasture. At least seven sorts of Lithosol have been differentiated in the Hawaiian Islands, their subdivision being based on the age of the parent rocks, which may vary from a few months to a million years, and on their texture, some being hard lavas and others loose cinders or "ashes".

In Puerto Rico, the only other remaining soils of any importance are Rendzina (black humic soils formed from soft, highly calcareous marls), and Alluvial Soils. This last-named group comprises the richest and most productive land in the island, being everywhere planted in sugar cane. It occupies extensive coastal flats, sometimes artificially irrigated, which have been laid out either as highly-organised estates, each with its large central sugar factory, or as small farms growing sugar cane under contract to the factories. The prosperity of Puerto Rico depends chiefly on the use of these alluvial soils and on the state of the sugar market.

MISCELLANEOUS NOTES.

Top Working Coffee.

A paper in *Bergcultures*, XV: 62-71 discusses the value of working over low-yielding coffee trees in the plantation. A system is explained, apparently hypothetical but based on data from an existing plantation, whereby the low yielders are gradually traced and reworked over a period of about six years, a low yielder being one that has failed to reach a certain standard of yield for two or three successive years. The standard required is computed annually in relation to the current year's total yield of the plantation. It is calculated that after grafting a plantation tree will show a reduced yield for three years on its previous production and will then give an increase. Failure to get worth while results from plantation grafting is often due to postponing the work till the trees are in a physically poor condition from any cause. In a non-clonal plantation the low yielders should be traced and dealt with at once. In the hypothetical case on the plantation in question the number would have been 47 per cent. of the whole.—(*Horticultural Abstracts*, XI, No. 2.)

* * *

New Uses for Maize.

Of special interest to Queensland maize-growers is the news that the United States Department of Agriculture is about to open a laboratory for the study of maize as an aid to industry associated with national defence. This will really be an extension of the work of investigation into the many industrial uses to which maize can be put, apart altogether from its uses as food for man and beast. It is proposed to explore the possibilities of maize as a base for synthetic rubber, plastics, fibres, and motor fuel. Last year, yarn, buttons, poker chips, and laminated boards made from a maize by-product were exhibited at the National Farm Chemurgic Conference, hence the possibilities sought by the research workers are not so very remote.

The by-product from which the articles mentioned are manufactured is a protein called zein, which constitutes about 10 per cent. of the whole maize. Its most practical use at present is for coating paper. It is oil and grease proof. Zein films are tasteless, odourless, and non-toxic, hence they are useful for food containers. Another use is in solid colour printing using aniline dyes. It is claimed that by using zein, fugitive dyes can be made more light-resistant, and that bleeding dyes can be made more resistant of water. In a clear state, zein can be formulated to carry bronze and aluminium powders. It is also made into a plaster which can be moulded in combination with other resins. It has several other industrial uses which suggest the immense possibilities of a crop which is now so largely used as a food for farm animals.

The result of the research work now in progress will be awaited with interest, especially by those who foresee the effect these new developments have on the future of our primary industries. —*Queensland Agricultural Journal*, Vol. 55, p. 91, 1941.

THE UTILISATION OF CULTIVATED FODDER GRASSES IN TRINIDAD.

By D. D. Paterson.
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Experiments with tropical fodder grasses grown as soiling crops on the farm of the Imperial College of Tropical Agriculture during the last ten years have demonstrated conclusively the following facts of practical interest to the livestock farmer in the West Indies.

(i) The herbage should be cut from 8 to 12 weeks old on a rotational system while it is still young and immature in order to obtain both good quality roughage and the maximum yield of food constituents per acre.

(ii) Tropical fodder grasses show considerable differences in their yields, nutritive quality and cultural requirements and it is important to choose a species suited to the environment in the widest sense of the term.

(iii) If the cutting rotation *i.e.* the period between successive cuts from the same stools, is one adapted to the species and cultural conditions, the cutting of the herbage at a young stage has a favourable and not an adverse influence on the yield of digestible nutrient, on the persistence of the crop and on the amount of cultural attention required to maintain it in a thriving condition over a period of years.

(iv) With the available species of fodder grass, it is quite impossible to obtain a protein rich herbage equivalent to young English pasture, but it is possible by cutting the herbage young, greatly to improve (*a*) on the standard of roughage at present used for stock feed, (*b*) on the yield of nutrient and (*c*) on the number of animals that can be fed per acre of fodder grass.

(v) Each year, thirty to fifty tons of herbage per acre are taken from the land and this represents a material drain on soil fertility. To maintain yield and quality of herbage over a number of years it is essential to apply periodic dressings of a suitable fertiliser. Where it is available, the dung or farmyard manure from the cattle pen is ideal for this purpose, but where this is required for other crops, it may be replaced by a complete artificial mixture, balanced in regard to the proportions of N, P, and K in accordance with the soil type, but commonly with a high percentage of nitrogen.

The experiments at the College have shown that the following perennial grasses arranged in approximate order of merit all make good fodder crops :—

Guatemala Grass (*Tripsacum laxum*, Nash).
Elephant Grass (*Pennisetum purpureum* Schumach).
Para Grass (*Brachiaria mutica* (Forssk) Staph).
Thin Cane (*Saccharum sinense* var. Uba or Coimbatore 213)

Guinea Grass (*Panicum maximum* Jacq.) which has done so well in some of the neighbouring colonies has been very disappointing under local conditions and compares very unfavourably with the other species in tests on the College Farm soils.

Although it is not the best of the four in yield or quality, the Guatemala Grass has been ranked first as it is a safe and particularly persistent fodder crop not susceptible to any serious pest or disease and continues to give a fair yield throughout the dry season. Elephant Grass suffers from the disadvantge that thriving fields of it may succumb sporadically to severe attacks of a Helminthosporium fungus. Recently a variety of this grass originally from Uganda, has shown itself to be apparently fairly resistant to this fungus, but further proof of its powers of withstanding a heavy attack is required. Para Grass is particularly good in damp but not swampy soil conditions, but it gives a negligible return in drought periods. The sugar cane is decidedly the poorest in yield and quality, although it is the one most commonly cultivated in Trinidad as a fodder crop today. For these grasses, full details regarding propagation, cultivation, spacing, and mowing rotations have already been published* and further elaboration on the same lines is

Fodder Crop.	Maturity of Herbage.	Yield of Green Herbage. (Tons per acre per annum).	Composition of Green Roughage. Dry Matter. %	Composition of Green Roughage. Crude Protein. %	Yield of Crude Protein. (lb. per Acre per Annum).
Uba Cane ...	2½ months ...	35	18.9	1.1	860
	6 do. ...	40	21.1	.74	660
	12 do. (*i.e.* ripe cane) ...	42	23.5	.80	710
Guatemala Grass ...	2½ months ...	32	18.6	1.31	940
	6 do. ...	38	20.9	.77	650
Elephant Grass ...	2 do. ...	45	13.7	1.05	1,060
Para Grass ...	2½ do. ...	34	23.6	1.52	1,160

* *Tropical Agriculture*, XVI, pp. 55-57, and *Jl. Exp. Agric.*, VI, pp. 323-40.

unnecessary. The customary practice of allowing herbage to mature until it has become fibrous and of low nutritive value before feeding it to stock is so prevalent that the following facts based on accurate and comparable data from a series of experiments carried out on the College Farm have been recorded here in order to stress again the fundamental importance of cutting soiling crops at a young stage and on an appropriate mowing rotation. (*See* Table.)

In the proximate analysis of any foodstuff, the protein is the most valuable constituent, and the crude protein content of similar types of produce provides a reasonable index of their relative nutritive quality. On this basis, it is clear that in allowing Uba Cane or Guatemala Grass herbage to grow until it is six months old or more before feeding it to stock, its nutritive content per unit has depreciated to less than 70 per cent. of that of the same herbage cut at 2½ months maturity. And it is not only the quality of the produce that suffers by feeding the herbage, but the actual yield of digestible nutrient per acre is less than when young produce is used, in spite of the fact that the gross tonnage of the old herbage is generally a little greater. Thus in the case of Guatemala Grass the yield in pounds of crude protein per acre from six months herbage is only about three quarters of that from the same crop cut at 2½ months. It is evident too that the Uba Cane compares very unfavourably in yield of nutrient with the other three fodder grasses. This does not necessarily hold good for all soils and all field conditions, but on the College farm the difference is very marked and quite conclusive and indicates that in any new areas to be planted up in perennial forage crops a trial of the other species would probably be profitable. Another factor is also of significance in the comparison between old and young herbage and that is the digestibility percentage of the nutrients. The digestibility of the older and more fibrous produce is not more than 75 per cent. of that of young succulent herbage, so that on the grounds of quality, quantity and digestibility of nutrient the young herbage has everything in its favour.

The data have been used to provide estimates of the starch equivalent or nutritive values of the different grades of roughage and it is possible to translate these facts into terms which should appeal to the practical stock farmer. Using linseed meal or oil meal as a standard cattle concentrate, the loss in productive nutrient per acre per year in feeding old Uba cane roughage in preference to young herbage cut at the optimum stage of maturity is equivalent to some 5 cwt. of oil meal. This amount of concentrate fed as a productive ration to a milch cow would suffice for the manufacture of 130 gallons of milk. The loss in feeding mature herbage of the other species is certainly not less than the figure given for Uba cane. The use of fibrous roughage represents a material and avoidable addition to the cost of feeding livestock.

There is also another way in which the use of young herbage in preference to old may affect a distinct saving to the stock farmer. There is a limit to the appetite of any aminal or in other words to the bulk of food it can consume in a day. For example, the appetite of an average sized ox does not exceed 22 to 25 lbs. of dry matter as fed in the daily ration. For the maintenance of such an animal 6 lbs. starch equivalent including .6 lb. protein equivalent are required, and with coarse fodder this may entail feeding over 100 lbs. of roughage for maintenance alone. The quantity of dry matter in that bulk of roughage will exceed 20 lbs. so that practically the total capacity of the animal for food absorption is used up. This makes it essential to supply the whole of the productive requirement for milk, meat, work or growth in the form of concentrates, in order not to inflate unduly the total dry matter in the ration. In contrast, with young herbage 60 lbs. of grass containing less than 15 lbs. of dry matter will fulfil the maintenance requirement. The animal's appetite is therefore not nearly exhausted and it becomes possible to supply a part if not the whole of the productive ration in the form of additional roughage. Thus, at least part of the concentrate ration can be replaced by home grown produce which should mean a material reduction in the stock food bill. It is estimated that with an average sample of green herbage at about eight weeks old, 7 lbs. will be equivalent to 1 lb. of a balanced concentrate mixture whereas with coarse roughage 10 or more pounds would be necessary and even then the ration would be low in protein and badly balanced.

In certain of the West Indian islands there is a real need to conserve fodder for feeding to the livestock in the dry months of the year. Apparently the simplest method of doing this would be in the form of silage, and from the conservation view point the use of young herbage cut in the flush season of the year has much to recommend it. It is undoubtedly easier and safer to make first grade silage from young succulent produce than from old roughage with a high proportion of hard fibrous culms. Even assuming that the cost of ensilage is the same for both types of roughage, and that the process is equally successful as a method of conservation, the nutritive quality of the finished silage will be much greater from young produce than from old, and for a given expenditure and silo capacity a larger quantity of food will be conserved if young herbage is used. Per cubic foot of silage the total food value of the young produce will be some 10 to 20 per cent. higher and the protein content up to 50 per cent. better than that from old produce.

To avoid any danger of misinterpretation of these facts and figures it is advisable to say that for the soiling and pasture grasses tested up to the present all attempts to produce rich herbage of the quality of young English pastures have been a complete failure. Even herbage cut at a week old has only one half to two thirds of the

protein content of English pasture grass, and with tropical soiling grasses the use of a cutting rotation less than six weeks leads to a heavy reduction in yield and to the premature dying out of a good proportion of the stools. In advocating the use of young herbage there can be no question of trying to produce a foodstuff equivalent in nutritive constituents to a concentrate such as can be made by the artificial drying of young grass in England. For the present, the feeding of young herbage in Trinidad, either fresh or in the form of silage, is merely a means of producing a high yield of better quality roughage equivalent in nutritive constituents to good meadow hay. That this represents a definite advance on the existing practice of using coarse mature roughage, cannot be denied in view of the fact that the daily maintenance ration for an ox is only 60 to 70 lbs. of young herbage as compared with over 100 lbs. of the older material. It is hoped that further research and the introduction of better quality species or strains, including a proportion of legumes, may make it possible in the future considerably to improve on the average quality of young herbaceous produce grown in tropical conditions.

CHEMICAL NOTES.

(Compiled by the College Department of Chemistry and Soil Science.)

Glucose Products.

Using a plant having a monthly capacity of 250,000 lbs. of hexahydric alcohols, it was found that mannitol and sorbitol could be readily and economically produced from glucose. Both these sugars are now being employed in making synthetic resins, which have special properties and besides are odourless and tasteless. Sorbitol is being used for the production of vitamin C for emulsifying and wetting agents, and for replacing glycerin in some of its applications, *e.g.* on printers' rolls.—(*The International Sugar Journal*, Vol. XLII, No. 500, p. 298.)

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Paints for the Tropics.

Paints found satisfactory in temperate zones fail rapidly in Cuba, where the adverse conditions are high humidity combined with strong sunlight. A pure white lead paint, successful in the U.S., may be a failure in the West Indies, while on the other hand, a pure zinc oxide may be a failure in the North, but successful in Cuba. Formerly the dark colours (blacks, maroons and dark greens) gave most difficulty in drying, but this can be remedied. Mildew resistance has been corrected, though it is worth noting that when mildew does occur it may be cleaned off with a dilute solution of trisodium phosphate followed by clean water. Colour fading is a difficult problem unless a high price be paid for certain colours, especially blues. Aluminium paints show excellent durability, but certain brands require to be used right away if their lustre is to be retained. Some of the new air-drying finishes produced with synthetic resins provide films which are highly resistant to chemical attack by acid or alkaline solutions or corrosive fumes. Red lead paint containing at least 20 lbs. to the gallon (U.S) has long been the best-known primer, but a new type which has been developed depends on the special properties of basic lead chromate, which, while being cheaper, is said to be more durable and more resistant to corrosion, especially when the metal on which it is coated has to be recleaned and re-painted. It is excellent for steel for exterior exposure, for cane cars and for sugar factory galvanized iron roofing.—(*The International Sugar Journal*, Vol. XLII, No. 500, p. 298.)

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Potash from Bagasse Furnace Ash.

To obtain potash from bagasse ash is a hopeless proposition in an economic sense. Although 100 pounds of the ash contain 2 to 7 per cent. of potash (K_2O) this potash is present in the form of insoluble silico-aluminates that have been produced by the heat of the furnace. In two experiments an attempt was made to leach out the potash by percolation with hot and cold water and with dilute acid, with results as follows :

	% K_2O Extracted	
	I	II
Hot water ,6 hrs.	0.3	0.8
Cold water, ½ hr.	0.12	—
Cold water, 1 hr.	0.16	—
Cold water, 1½ hrs.	0.18	—
HCl (1 : 1)	2.90	2.50
Unburned carbon	3.10	0.50
Moisture content	0.20	0.20

The ash of the bagasse from a cane crop yielding at the rate of 137 metric tons per acre hectare will give about 3.1 kilograms (6.8 lbs.) of K_2O when extracted with cold water, which obviously is hardly worth while. The winning of potash from cane molasses has much better prospects. The ash of the molasses from a cane crop of the size above mentioned will contain about 150 kilograms (330 lbs.) of K_2O. However, when molasses is burned with a view to obtaining potash the operation should not be carried out in a bagasse-fired furnace, as some of the K_2O in the molasses may be insolubilized by reaction with the bagasse ash. As a matter of fact the ash of bagasse is characterized far less by its potash content than by its content of sesquioxides and silica ; it is a silicate material fairly well adapted for making glass, which has been done on a semi-technical scale in the Philippines.—(*Facts about Sugar*, Vol. 35, No. 10, p. 31.)